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DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
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MILLING METHODS AND COSTS AT THE CONCENTRATOR OF THE ST. JOSEPH LEAD CO., ATLANTA, IDAHO

BY

E. D. GARDNER

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INTRODUCTION

This paper is one of a series on milling methods being published by the United States Bureau of Mines.

Atlanta is in Elmore County, Idaho, about 80 miles from the railroad at Mountain Home, Idaho.

The concentrator is at an elevation of 6,000 feet and located in a timbered, well-watered region of relatively heavy snowfall. The snow, however, does not seriously affect local operations. The truck road to Mountain Home, which passes over a mountain range, is closed each winter from about November 1 to June 15. During this period concentrates are stored and bullion is shipped by airplane. Power is generated by a Diesel engine and by an auxiliary hydroelectric plant.

Gold is the principal metal produced; the ore also contains an appreciable quantity of silver.

The ore is mined by cut-and-fill and square-set methods and trammed directly from the haulage adit to the mill bins. It reached the bins before the sulphides oxidize appreciably. The concentrator has a capacity of about 225 tons per 24 hours. A crew of 20 men is employed in the mill; although the mill is operated 7 days per week, the men work only 6 days. An average saving is made of about 90 percent of the gold and 94 percent of the silver. About 75 percent of the metals is recovered as bullion from amalgamation plates; the other 25 percent is obtained in flotation concentrates.

The mill was built during 1931 and 1932 and began operation on February 1, 1932. Previous operators had treated the ore from the mine in an amalgamating and gravity-concentration plant. The improved recovery of the metals by flotation makes it possible to treat ores that could not have been handled profitably under the old conditions.

1/ The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6836."

2/ Supervising engineer, U.S. Bureau of Mines Southwest Experiment Station, Tucson, Ariz.

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The information contained in this paper was supplied by F. W. Skeels, general manager, and L. D. Yundt, mill superintendent, both of the Atlanta division, St. Joseph Lead Co.

ORE TREATED

The ore consists of quartz containing disseminated fine crystals of arsenopyrite and pyrite. Crushed and altered granite is the principal gangue material. The gold occurs free and with the sulphides. An attempt is made to save all of the sulphides in the mill.

METHOD OF MILLING

Crushing

The flow sheet of the crushing section of the mill is shown in figure 1. The ore as brought from the mine is dumped through a grizzly, with a spacing of 8 inches between bars, into a 1,066-ton crude-ore bin. Oversize on the grizzly is broken by hammers. The proportion of oversize is small, as the ore is passed through the same size grizzly in the mine. The ore bin is of conventional construction, except the front, which consists of locally cut logs lined with plank. The ore is drawn from the bin by a Stephens-Adamson pan feeder, 36 inches wide and 5 feet 6 inches from center to center, to a grizzly with bars set 1 1/4 inches apart. The grizzly undersize goes to a bucket elevator, 51 feet between centers and with 6 1/4- by 14-inch buckets spaced on 18-inch centers. This elevator discharges onto a 4- by 5-foot St. Joe vibrating screen. The screen opening is one half inch; it is vibrated 1,200 times per minute. The undersize from the screen drops directly into a flat-bottomed, 600-ton, fine-ore bin. The oversize from the screen passes down a chute to a set of 14- by 36-inch, Joplin, gear-driven spring rolls. These rolls operate in a closed circuit between the elevator and the St. Joe screen. The grizzly oversize drops into a 24- by 14-inch, Blake-type, Carterville jaw crusher. The discharge from the crusher goes to a second set of 14- by 36-inch Joplin rolls and thence to the elevator.

The crushing plant is protected from tramp iron by a 39-inch 20-kva Cutler-Hammer magnet. This magnet is energized by the same motor-generator set which charges to Exide batteries used in the underground haulage. The crushing plant is driven by a 100-hp. motor, belt-connected to a line shaft. Crushing is done on two 5-hour shifts.

Grinding

The crushed-ore bin is provided with four gates in the bottom. An 18-inch belt feeder from each gate discharges onto a main belt feeder, which is driven by a 10-hp. motor and travels 71 feet per minute; this in turn empties into a Denver Equipment Co. automatic sampler. (See fig. 2.) The ore from the sampler is mixed with enough water to give a pulp density of 60 percent solids and then fed into a 4- by 12-foot Marathon ball mill running at 32 r.p.m.

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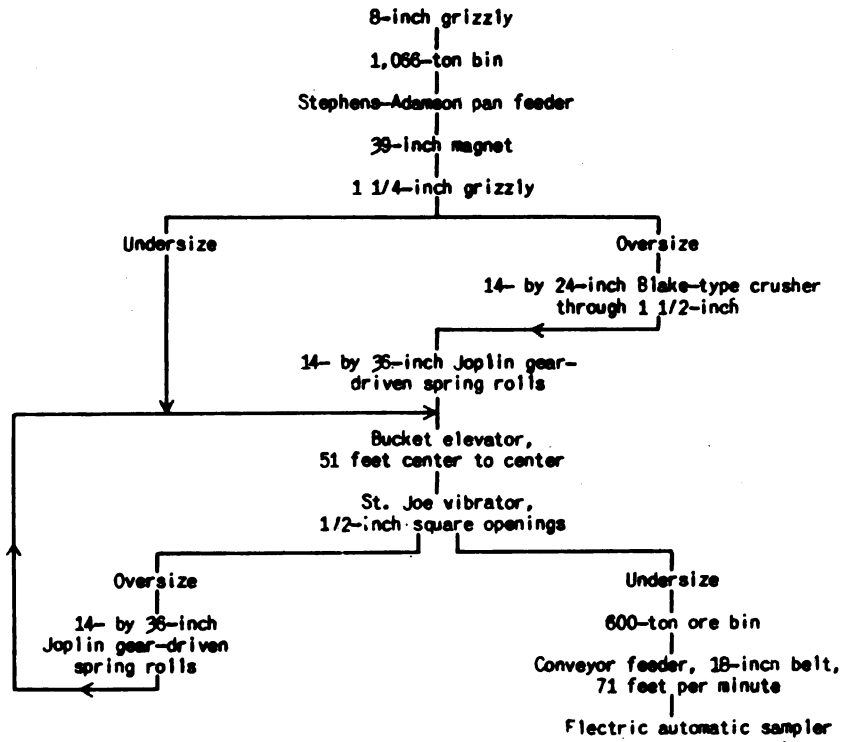

Figure 1.- Flow sheet of crushing section.

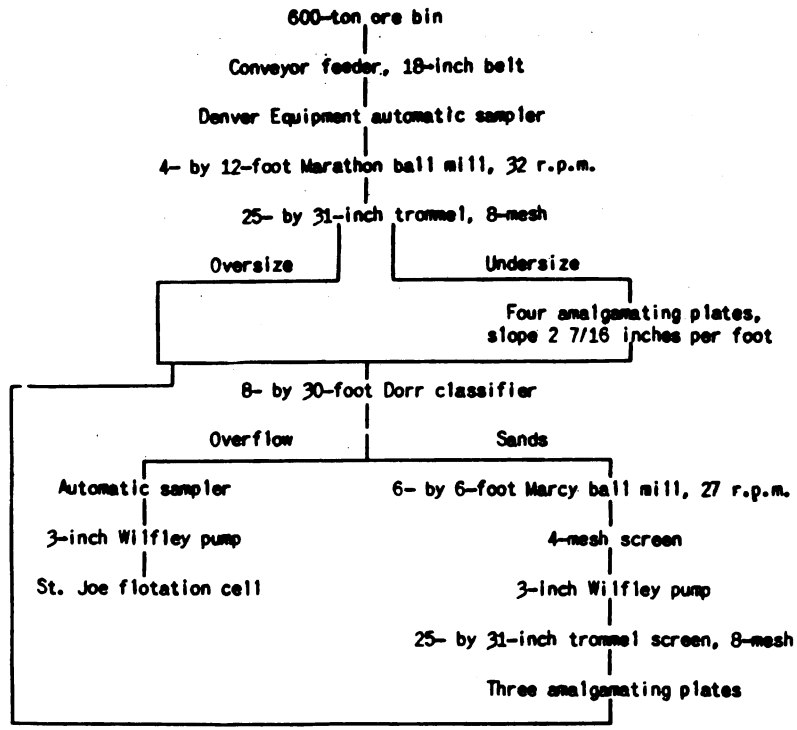

Figure 2.- Flow sheet of grinding and amalgamating section.

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The mill which was originally designed for rods has been remodeled to use balls; the load is 12,000 pounds of drop-forged steel balls. Daily addition of steel balls are made to replace consumption. Equal weights of 4- and 3-inch balls are used in the mill.

The pulp is screened in a 25- by 31-inch, conical, 8-mesh trommel attached to the mill. The screen opening is 0.071 inch and the wire diameter 0.054 inch. The undersize, amounting to about 75 percent of the feed, passes over four amalgamation plates and thence to an 8- by 30-foot Dorr classifier; the oversize goes directly to the classifier. Six and eight tenths percent of the oversize is plus 4-mesh material.

The classifier is driven by a 10-hp. motor and is in closed circuit with a 6- by 6-foot Marcy ball mill which revolves at 27 r.p.m.; 5,000 pounds of 3-inch and 5,000 pounds of 2 1/2-inch forged steel balls are used; the circulating load is approximately 250 percent. The discharge from the Marcy mill goes over a 4-mesh screen and is then elevated by a 3-inch Wilfley pump to a 25- by 31-inch trommel with an 8-mesh screen, whence it passes over three amalgamation plates and back to the classifier. The overflow from the classifier, which was 80 percent minus 200-mesh, goes to a 3-inch Wilfley pump and thence to a flotation machine.

The Marathon and Marcy mills are driven by a 240-hp. synchronous motor with Medart V belt and a 12-inch, 5-ply belt drive.

Amalgamation Plates

The amalgamation unit consists of 7 plates, of which 3 are 4 feet 3 inches by 9 feet 6 inches and 4 are 4 by 7 feet in size. The slope is 2 7/16 inches to the foot.

The undersize of the screen on the discharge of the Marathon mill constitutes the feed to four of the plates. It is 100 percent minus 8-mesh, 3 percent plus 20-mesh, and 33 percent minus 35-mesh. The Marcy mill discharge is pumped back and put over the remaining three plates.

The cooling water from the Diesel engine is used in the winter to keep the temperature of the pulp going over the plates at a minimum of 45°F.

The plates are dressed one at a time every 2 hours. After the feed is diverted, a plate is washed with clear water from a hose. Quicksilver is applied to spots where the amalgam is hard. The plate is then brushed lightly with a dilute solution of ammonium chloride and the feed turned back on.

Quicksilver used for dressing the plates is cleaned with sulphuric acid to remove oil. An average of about 40 ounces is used for each dressing of the plates.

The amalgam is removed from the plates once each 24 hours. After the feed is shut off a plate is washed clean with water from a hose. Soft amalgam is scraped to the top of the plate with a section of rubber belting and taken

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off with putty knives. Then the plate is washed with caustic soda solution and hosed off. Enough quicksilver is sprinkled on the plate to bring the amalgam remaining on it to the proper hardness.

About 200 ounces of amalgam from the previous day's clean-up is used in dressing the plates. Enough amalgam is applied to each plate to protect the plate surface from scouring and to aid in amalgamation of the gold and silver. This amalgam is cleaned with concentrated sulphuric acid then washed with water until no acid remains. After the right amount of clean amalgam has been applied to the plate, enough quicksilver to bring the amalgam to the proper hardness is sprinkled on and the plate brushed with ammonium chloride; the movement of the brushes makes distinct transverse riffles across the plates. The finished plate has a silver-white appearance and is now ready for use.

Traps

Traps 8 inches deep and with lengths equal to the width of the plates are used at the ends of the plates; they are cleaned up once each day. When the amalgamation unit is running smoothly 1/2 to 1 pound of quicksilver is caught in each trap daily. On rare occasions when the plates do not take the dressing properly, nearly half of the amalgam may be found in the traps.

Riffles

A 3-foot section of transverse riffles is placed in the main launder below the plates to catch any coarse or rusty gold and amalgam passing over the plates and through the quicksilver traps. The 24 riffles are made of 20-gage metal strips 1 1/2 inches high on 1 1/2-inch centers; they are tilted downstream. The riffles pack with sulphides, but the velocity of the pulp is sufficient to maintain a transverse hollow back of each riffle. The gold and amalgam are retained in the hollow. The riffles are cleaned up every 6 days, and about 5 pounds of concentrate is obtained.

Gold and amalgam are panned from the concentrate. The concentrate is then run over a laboratory amalgamation plate, the gold removed, and the balance put into concentrates. The pyrite is usually cemented and rusty and the quicksilver foul.

Six tenths pound of copper sulphate, 2.0 pounds of soda ash, and 0.01 pound of potassium-xanthate per ton of ore are added to the Marcy-mill discharge. The presence of these reagents on the three plates amalgamating the Marcy discharge has increased the amalgamation recovery.

Treatment of Amalgam

The amalgam, cleaned daily from the plates, together with amalgam from traps and riffles, is ground 3 hours in a Stearns-Rogers laboratory ball mill with hot water and enough quicksilver to make the amalgam soft. The ground amalgam is then washed with hot water and cleaned with a magnet until all the metallic iron and sulphides have been removed. The amalgam is then wiped dry with cloths. Two hundred ounces is set aside for platedressing the following

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day; the remaining amalgam is squeezed in an amalgam press. This squeezed amalgam is very hard and contains from 58 to 65 percent of quicksilver.

The compressed-air press, which consists of a 3-inch pipe 13 inches long, is capped on both ends. One-eighth-inch holes spaced one fourth inch center to center have been drilled in the lower cap. The amalgam is placed on two thicknesses of muslin (see fig. 3) lying on a 60-mesh wire screen, which in turn is on the lower cap. Air at 100 pounds per square inch pressure is introduced through a 1/4-inch pipe tapped into the press near the top; the moisture and oil in the air pipe is blown out through a by-pass valve before the air is used in the press.

Retorting

The clean-up is retorted once a week in a no. 14 retort. The fire box in which the retort is heated is 12 by 14 inches; the bottom of the fire box is 10 inches from the bottom of the retort. Crude oil is used for fuel; a Denver fire-clay no. 250 centrifugal fan supplies the draft. A 3/4-inch pipe extends from the retort to a 2 1/2- by 36-inch condenser.

About 1,400 ounces of amalgam is treated and about 560 ounces of sponge bullion obtained. The sponge is melted in a no. 50 graphite crucible with 5 pounds of soda ash, 2 pounds of borax, and 1 pound of silica in an oil-fired furnace. The length of time required to make a fusion is 4 hours. The bullion is poured into a 4 1/2- by 4- by 11-inch cast-iron mold. The bricks weigh 830 to 880 ounces. The slag is broken up and fed to the Marcy mill.

Each bullion bar is sampled by drilling two 3/16-inch-diameter holes halfway through the brick on the center line and 1 inch from the ends on opposite sides of the bar. The sampling checked almost exactly with results from the United States assay office at Boise, to which the bullion was formerly consigned.

The bars range from 500 to 560 parts of gold per 1,000, usually near the latter figure. The total fineness of gold and silver is about 980; the impurity is principally speiss and metallic arsenic. The bullion is shipped each week by first-class mail to the mint. Postage, insurance, and mint charges total 8 cents per ounce. The amalgam and gold are insured from the time they leave the mill building proper. A watchman goes through the mill hourly; no other precautions against theft were taken in the mill.

Flotation

The classifier feed goes to a 3-cell St. Joe flotation machine. The first cell, 42 feet long, is a rougher; the second, 5 feet long, a cleaner; and the third, 2 1/2 feet long, a recleaner. The feed enters at one end of the first cell; the concentrate from the first 14 feet flows to the second cell, which in turn delivers its concentrate to the recleaner. (See fig. 4.) The rejects from the last two cells, together with the middling from the first cell, are returned to the head of the first cell by a 3-inch Wilfley pump run by a 10-hp. motor. The tailing from the rougher goes to waste.

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The flotation feed is 80 percent minus 200-mesh and contains 27 percent solids. Tests show that an improved recovery does not result from finer grinding.

The three cells are in line and are supplied with air from a 16-inch pipe under a pressure of seven eighths inch of mercury. The branch lines leading down into the cells are 4 inches in diameter and 9 inches apart. The orifices at the bottom of the branch pipes are five sixteenths inch in diameter. Pressure is supplied by a 27-hp., General-Electric-type, F.S. 355, centrifugal compressor that ran at 3,500 r.p.m.

Mill slop is collected in a 5- by 12-foot circular sump, whence it is returned to the classifier every 2 weeks by means of a sand pump. An overflow of water from the sump carried away most of the lubricating oil.

Reagents

As mentioned before, 2.0 pounds of soda ash, 0.6 pound of copper sulphate, and 0.01 pound of potassium xanthate are added to the Marcy-mill discharge. Eighty-four thousandths (0.084) pound of cresylic acid, 0.017 pound of pine oil, 0.13 pound of Barrett no. 4 creosote, 0.064 pound of potassium xanthate, and 0.067 pound of aerofloat no. 25 are added to the flotation circuit ahead of the 3-inch Wilfley pump. The soda ash (10-percent solution) is prepared by agitating the salt in hot water by means of compressed air until it dissolves. The reagents are added to the pulp by Denver Equipment Co. bucket feeders.

Filter

The flotation concentrate goes to a 6-foot, 3-disk, Oliver-United filter run by a 7-hp. motor. A 9- by 12-inch, Ingersoll-Rand, vacuum pump run by a 25-hp. motor at 200 r.p.m. maintains a vacuum of about 18 inches of water. Cake from the filter drops directly upon a drier, which consists of hot plates heated by the exhaust gases from the Diesel. The concentrate is sacked in 130-pound bags and placed in storage.

Flotation Concentrate

The concentrate is shipped during the summer to Garfield, Utah. The rate for smelting is a flat charge of $5 per ton of concentrates. There are no penalties or bonuses charged against this concentrate.

TAILINGS DISPOSAL

The tailing is conveyed through a 500-foot launder to a 1,000-foot ditch leading to three settling ponds built one below the other in a gulch. Only one pond is used at a time. The overflow from the ponds goes to a clarifying pond with an area of about 300 square yards. The water as it leaves this pond is slightly "milky." The dams were started by laying 3 to 4 rows of round-timber cribbing across the bottom of the gulch and then filling in with sand from the tailing.

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SAMPLING

Automatic samples are taken of the mill feed as it comes from the fine-ore storage bin, of the classifier overflow, and of the mill tailings. The pulp samples are obtained by means of Denver Equipment Co. motor-driven samplers that take cuts every 12 minutes.

All samples, both from the mine and mill, are prepared for assaying in the mill. The equipment consists of 1 Denver Clay 4- by 6-inch crusher, 2 Braun pulverizers, and 1 air-pressure filter. The sample room also contains a Ro-Tap screen for making screen analyses of the mill products.

A close assay control is maintained in both the mine and mill. An average of 45 samples is assayed daily for gold and silver. Six samples from the mill are tested for metallics, and three are run for insolubles each day.

POWER

Power is supplied by an 8-cylinder, 360-hp., Diesel engine (6,000 feet above sea level) and an auxiliary hydroelectric plant. The Diesel is of the type used in German submarines; it was purchased in Germany. No American manufacturer could make delivery of a Diesel plant during the summer the mill was being built in time to get it to the property before the roads closed for the winter. The engine is direct connected to a 375-kva, 3-phase, 60-cycle, 480-volt, Westinghouse generator that runs at 360 r.p.m.

A supply of extra valves and valve stems are kept in stock. Other repair parts are made in the mine shops by the chief Diesel operator who is a machinist.

The winter supply of fuel oil for the Diesel is brought in before the roads are closed and stored in a 108,000-gallon tank. The oil is filtered through a 3-ply filter pack before it goes to the engine. After the filter had been installed no trouble was experienced with nozzles choking as before.

The plant is run by a mechanic and two helpers on day shift and by one operator on each of the other two shifts. The two helpers spend about one half their time in the shops and one half in the mill. The mine air compressor is in the Diesel building and is operated by the Diesel crew.

The hydroelectric plant, consisting of a very old model Ingersol turbine wheel and a 125-hp. generator, is on the Middle Fork of the Boise River about 2 1/2 miles from the mill. During low water the capacity of the plant is reduced to 40 hp. The head on the wheel is 60 feet. The current is transmitted at 2,200 volts. Both plants are synchronized; switchboards and synchronizing apparatus are in the Diesel engineroom.

The connected load of the mine and mill is 353 hp. The average horsepower used for the different departments of the mill is shown in the following table:

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Average horsepower used (voltage, 440)

	Horsepower
Crushing	41
Fine grinding	135
Flotation	37
Filtering	7
Miscellaneous	10
Total	230

The mill building was heated during the winter by the exhaust gases from the Diesel engine.

WATER SUPPLY

Water from a local stream is flumed along the mountainside into a series of 18- by 23-foot tanks at a point 150 feet above the mill. The mill is supplied through one pipe line; a second line provides fire protection to the mill and other camp buildings. Approximately 85 to 100 gallons of water is used per minute in the mill.

TRANSPORTATION

The concentrates are hauled 85 miles to the railroad during the summer months. Freight is hauled from the railroad to Atlanta on the return load. Heavy supplies, including fuel oil, are hauled to the mine during the summer and stored for winter use.

The minimum freight rate on ore from Mountain Home to Salt Lake Valley smelters is $2.75 per ton. The rate on high-grade concentrates is about $28 per ton.

During the winter Atlanta is served by an airplane company which brings in mail and supplies and carries passengers; six trips are made each week. The company built and maintains the landing field. A rate of 5 cents per pound is charged for bringing in supplies. The passenger fare is $20 per round trip or $10 one way. Special trips cost $40. The distance from Boise, Idaho, is about 60 miles; 30 to 40 minutes is taken for the trip. The plane used has a carrying capacity of 2,000 pounds.

LABOR

The wage scale in May 1934 was as follows:

Amalgamators	$5.50
Flotation operators	5.50
Ball-mill operators	5.00
Filter operators	4.50
Laborers	4.50

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The company runs a boarding house for single men. Board and room cost $1.25 per day. Men with families live in the village of Atlanta about a mile from the mine.

PLANT RECOVERY AND COSTS

Metallurgical data are given in table 1, screen sizes in table 2, operating data in table 3, and operating costs in table 4.

TABLE 1. - Metallurgical data of the Atlanta mill, April 1934

Head assay:		
Gold	Ounces per ton	0.467
Silver	do	1.541
Total tons treated		6,575
Hours operated per day		24
Recoveries:		
Gold	percent	89.55
Silver	do	94.58
Recoveries by amalgamation		70
Recoveries by flotation		30
Concentration ratio		55
Tailing assay:		
Gold	ounces per ton	0.04
Silver	do	.085
Concentrate, weight	tons	119.75
Concentrate assay:		
Gold	ounces per ton	5.703
Silver	do	61.63
Insoluble	percent	15.0
Lead	do	.3
Copper	do	.3
Arsenic	do	6.0
Iron	do	38.0

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TABLE 2. - Screen size

To crusher	minus 8 inches
To rolls	minus 1 1/4 inches
To Marathon mill	minus 1/2 inch
To Marcy mill	minus 4 mesh
To flotation	80 percent minus 200 mesh
To plates	3 percent plus 20 mesh 33 percent minus 35 mesh 100 percent minus 10 mesh (Tyler Standard)
Trommel oversize	6.8 percent plus 4 mesh

TABLE 3. - Operating data at the Atlanta mill for April 1934

Days operated	30
Men employed per 24 hours	20
Tons treated per man-shift	10.94
Ball consumption, pounds of steel per ton of ore:	
Marathon mill	1.65
Marcy mill	1.828
Total	3.478
Reagent consumption, pounds per ton of ore:	
Aerofloat	0.067
Potassium xanthate	.074
Cresylic acid	.084
Pine oil	.017
Barrett no. 4	.13
Soda ash	2.00
Mercury	.006
Copper sulphate	.60

TABLE 4. - Operating costs at the Atlanta mill for April 1934

(Tons treated, 5,904)

	Labor	Supplies	Power	Total
Crushing	$0.071	$0.011	$0.02	$0.102
Fine grinding	.089	.221	.18	.49
Amalgamation	.037	.045	.....	.082
Flotation	.072	.142	.048	.262
Filtering	.06	.002	.007	.069
Tailing disposal	.056	.001	.....	.057
Miscellaneous	.049	.....	.009	.058
Superintendence	.042	.....	.....	.042
Total	0.476	0.422	0.264	1.162

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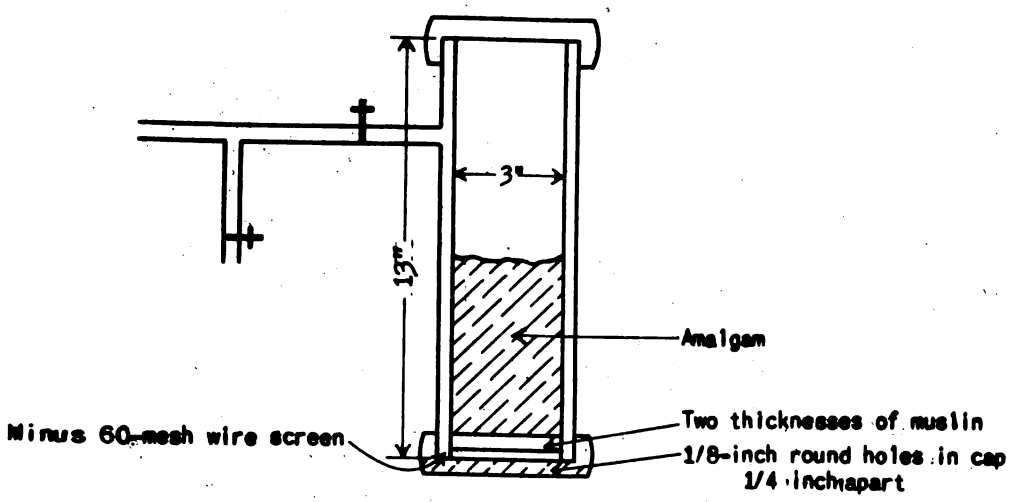

Figure 3.- Compressed-air amalgam press.

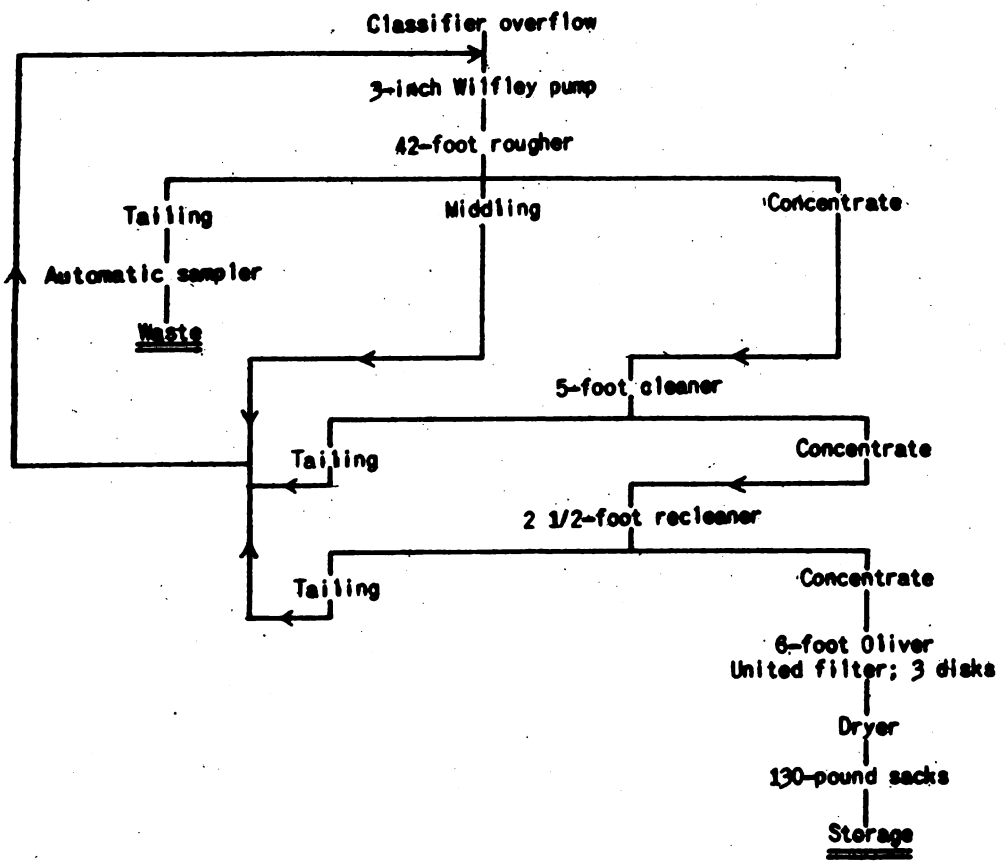

Figure 4.- Flow sheet of flotation circuit.

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